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ARTICLE

Adaptive Governance and Managing Resilience to Natural Hazards

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Abstract The increasing frequency, intensity, and severity of natural hazards is one of the most pressing global environmental change problems. From the local to the global level, governments and civil society need to increase resilience to these hazards. Despite what is now a very sizeable literature on designing governance systems to produce resilience, a substantial gap in the natural hazards scholarship remains because most studies have lacked grounding in comparable theories on governing for resilience. This article contributes to interdisciplinary research on the conceptual understanding of the interlinkages of adaptive governance (AG), resilience, and disaster risk reduction (DRR). Through better understanding of diversity of terminology, terms, and characteristics, we take a step forward towards mutual learning and intellectual experimentation between the three concepts. Our review shows that there are four characteristics of AG that are important to help increase resilience to natural hazards. These are polycentric and multilayered institutions, participation and collaboration, self-organization and networks, and learning and innovation. The article examines the development, trade-offs, and benefits that arise from the implementation of the AG characteristics, and reviews their influence on resilience. Hazard and disaster case studies are then examined to see how each AG characteristic is viewed and implemented in disaster contexts. Based on this analysis, the contributions of AG to the DRR literature are identified, before outlining the implications for theory and further research.

Keywords adaptive governance, disaster resilience, disaster risk reduction, natural hazards

1 Introduction

The world is facing an increase in the frequency, intensity, and severity of natural hazards. Greater resilience is needed in human hazards management systems to cope with this environmental change problem. This goal can be attained by increasing the adaptability of current modes of governance to environmental change (Lebel et al. 2006). For many scholars, building resilience is the ultimate purpose of any disaster risk reduction (DRR) governance activity. Designing governance systems to build resilience is, however, far from the exclusive domain of DRR studies. This article discusses a different strand of governance literature that so far has rarely been explored or employed together with DRR, but that offers substantial insights for the disaster field. Ignoring the interplay between related bodies of scholarship can lead to isolated evolution among different bodies of work. The result is to impede the development of effective environmental and natural disaster governance as mutually beneficial lessons are lost amongst scholarly differentiation (Slavíková, Kluvánková-Oravská, and Jílková 2010).

The intention of this article is to call attention to the separate evolution of a body of governance scholarship that like DRR is similarly concerned with building resilient and adaptive governance systems. Here we understand the term governance as meaning the intentional shaping of the flow of events so as to realize desired public goods (Parker and Braithwaite 2003). This is distinct from the concept of government, which we define as political authority / state control (Freeman 1997–1998). Adaptive approaches to governance have been described using a variety of terms and theories, but we use the term adaptive governance (AG) to emphasize environmental and natural resource governance approaches that share some or all of the following principles: polycentric and multilayered institutions, participation and collaboration, self-organization and networks, and learning and innovation. This article aims to highlight potential similarities and differences between AG and DRR and their discussion of designing adaptive governance systems that build resilience. By doing so, we seek to offer some new perspectives and links, and foremost, to open the field for future discussion.

We intend to answer several important questions: What are the important characteristics of AG that influence capacity to manage resilience? How are these characteristics perceived, implemented, and experienced in trying to build resilience to disasters, as documented in the DRR literature? What are the lessons from implementation of those identified characteristics in AG literature, which have been shown to increase resilience, but are not yet fully utilized in DRR planning and implementation?

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In the following section we review the AG literature and present our views on the relationships among four AG characteristics in helping to build resilience. Then we present the interlinkages between AG, resilience, and DRR. The key contribution of this review is our systematic analysis of each of these characteristics and the conceptual development, barriers, and opportunities that arise from their implementation, as discussed in AG literature. The next step involves a review of their influence on resilience. Case studies drawn from the hazard and disaster literatures are examined to see how each characteristic is perceived and implemented in these contexts. Finally, we analyze the wider implications of AG for DRR.

2 Review of Adaptive Governance Literature

The adaptive governance literature is not derived from a single school of thought or theory. Rather it stems from many diverse sources. Although there have been nascent discussions of AG at the international scale, the large majority of scholarship to date falls within three broad groupings: adaptive management, cooperative management, and collaborative governance. These groups of scholarship are outlined in turn below, before identifying some defining features of the AG approach.

The first broad area of AG scholarship emerged from work on social-ecological systems and adaptive management (AM). Holling (1978) proposed the AM concept as "active" scientific hypothesis testing "in the field." Management interventions in ecosystems could be treated as experiments from which managers and scientists can learn and adapt (Holling 1978; Dovers 2003a). The concept has since been applied more broadly. Walters and Hilborn (1978), for instance, proposed a distinction between passive and active management, by which they meant a difference in the extent of management interventions employed to reduce uncertainty and the recognition of learning within the management process (see also Walters 1986). Lee reviewed the AM concept (1993) and later appraised it as a policy implementation approach (1999). Gunderson (1999) subsequently proposed the concept of adaptive environmental assessment and management, which included tenets of learning, informal networks, and multiple stakeholders. Panarchy was subsequently developed (Gunderson and Holling 2002). This idea describes a nested set of adaptive cycles and multiple connections between changes that differ in speed and scale. Resilience comes from the nested cycles and interactions among "fast" and "slow" variables that impact adaptive cycles (Gunderson 1999; Plummer 2009).

The second major grouping of AG scholarship draws on the first to combine the insights of adaptive management with a cooperative approach to managing local resources. One prominent line of the cooperative management literature is centered around the concept of comanagement, which traditionally focused on shared resources, such as fisheries and forests, and a form of power-sharing arrangement between the State and a community of resource users (Carlsson and Berkes 2005). The comanagement concept has since been broadened to include a wider array of management arrangements and models (Carlsson and Berkes 2005; Plummer and Fennell 2009), including comanagement as a continuous problem-solving process (Plummer 2009). This led to a concept of "adaptive comanagement," which combines AM and cooperative management (Olsson, Folke, and Berkes 2004). While there is no definitive model of adaptive comanagement, common principles include a management process that is dynamic, multilevel, polycentric, and seeks to find some balance between decentralized and centralized control (Olsson, Folke, and Berkes 2004; Folke et al. 2005; Plummer 2009). One of the key underlying foci of this concept is that changes within the environment are becoming more complex and that social and ecological systems are intertwined and therefore these systems as a whole need to be able to learn and adapt to change (Folke 2006). Resilience is adopted as a term describing this ability (Carpenter et al. 2001).

Another prominent line of theory within the cooperative management literature is the work of Ostrom and her collaborators that have used fieldwork and game theory studies to explore effective and sustainable comanagement of common pool resources (Ostrom 1990, 2000). This research has identified a range of conditions associated with an increased likelihood of cooperative self-governance arrangements in common pool resource contexts (Ostrom 1990). Ostrom has also integrated and built on this work to explore ideas of polycentricism (2010) and adaptive governance in complex large-scale systems (for example, climate change). In particular, Dietz, Ostrom, and Stern (2003) propose five requirements of AG (provide information, deal with conflict, induce rule compliance, provide infrastructure, and encourage adaptation) and eight strategies for meeting these requirements (devise rules relevant with ecological conditions, define boundaries of resources and users, set accountability mechanisms, apply graduated sanctions, establish low-cost mechanism for conflict resolution, encourage participation/analytic deliberation, apply nesting, and employ institutional variety).

The third and final group of AG scholarship is derived from legal and natural resource management scholarship and focuses on collaborative governance of environmental problems (Wondolleck and Yaffee 2000; Sabatier et al. 2005; Holley, Gunningham, and Shearing 2011). Recent policy trends and theoretical ideas have informed this scholarship, including, ecosystem management (Odum 1953), adaptive and experimentalist learning (Dewey 1948 [1920]; Holling 1978; Walters 1986; Lee 1993), the discourse of "sustainable development" (Brundtland 1987), and the rise in popularity of participatory (Arnstein 1969), deliberative (Dryzek 2000), and civic (Putnam 1993) democracy. A range of novel

environmental governance theories have embraced these trends, including democratic experimentalism (Dorf and Sabel 1998), collaborative governance (Freeman 1997–1998), multilevel governance (Hooghe and Marks 2003), civic environmentalism (John 1994), collaborative ecosystem governance (Karkkainen 2001), adaptive governance (Brunner et al. 2005; Scholz and Stiftel 2005), and new environmental governance (Holley, Gunningham, and Shearing 2011). Although divergent in their theoretical pedigree, these theories are bound together through an engagement with forms of environmental policy that favor less rigid, less uniform, less prescriptive, and less hierarchical approaches to governing and embrace more collaborative, decentralized decision-making approaches that devolve control to participatory and multi-stakeholder groups, embrace flexibility and multilevel arrangements, and pursue explicitly adaptive and arguably more effective means of addressing complex environmental challenges (Holley 2010a).

There is great variation both within and across these bodies of scholarship. It is a broad and diverse field, containing many different terminologies, methodologies, and theoretical vantage points on adaptive forms of governance. For instance, some approaches have primarily focused on AG involving smaller-scale communities, while others focus on environmental management of much larger ecosystems. The theories also vary in ideas, some rooted in ecological systems, and others based on legal and governance traditions. Most importantly from the perspective of this article, there is also variation in the emphasis of resilience. In many AG theories, governing to build resilience remains at the forefront of normative design, particularly in the adaptive management and cooperative management groupings. In other theories, the emphasis on resilience itself is more implicit and intertwined with a focus on developing governance approaches that are flexible, adaptive, and capable of responding to new knowledge and change in social and ecological systems. Despite these differences, there is also integration across these scholarships, particularly as most draw on adaptive management concepts. Despite extensive variation, at a broad level there are characteristics that are common across most AG theories. Although there is no single AG model per se, each grouping of theory emphasizes an approach to governing that shares some or all of the following principles: polycentric and multilayered institutions, participation and collaboration, self-organization and networks, and learning and innovation. We use the term "adaptive governance" to group these diverse theories together. We acknowledge that the importance of these characteristics are contestable and, consistent with evolving understandings of AG, and not all of these characteristics need to be present for a particular theory or example of AG to fall within this category. We also recognize there is a risk of overgeneralizing and of obscuring divergent tendencies within the literature; it is important to remain alert to such differences.

3 Interlinkages between Adaptive Governance, Resilience, and Disaster Risk Reduction

Resilience is at the center of the exploration of AG and this concept becomes the bridge for our interdisciplinary examination of AG and DRR. The concept of resilience has been developed, adopted, and interpreted differently in different fields of study (Djalante and Thomalla 2011). It was originally developed in the field of ecology (Holling 1973) and subsequently in engineering (Wildavsky 1991), social-ecological systems (Folke 2006), natural hazards (see, for example, Paton and Johnston 2006; Tierney and Bruneau 2007), development studies (Gaillard 2010), psychology (Crittenden 1985; Norris et al. 2008; Van Vliet 2008), and is now used widely in the media. It is increasingly associated with research in vulnerability, and adaptive capacity (Gallopín 2006; Miller et al. 2010). We understand resilience as the ability to self-organize, learn, and adapt (Carpenter et al. 2001). Lebel et al. (2006) note that a capacity for self-organization means that a system needs the ability to maintain and recreate its identity and to buffer itself from outside impacts. The ability to learn and adapt means that a system is able to achieve its management objectives better over time and adjust those control measures should the context change.

So resilience as a concept is used both explicitly and to a lesser extent implicitly in AG scholarship. Resilience is the ultimate goal for reducing disaster risks (UNISDR 2007). In DRR, resilience is defined as the ability of a community or society exposed to hazards to resist, absorb, accommodate, and recover from hazards timely and efficiently (UNISDR 2009). We adopt the United Nations International Strategy for Disaster Reduction definition of DRR (UNISDR 2009, 10) as a systematic effort to reduce disaster risks through analyzing and managing the causal factors of disasters including the reduction of vulnerability and improved preparedness for adverse events.

Figure 1 shows the interlinkages between key characteristics of AG that help build resilience to natural hazards. The solid-line arrows show the main relationships among the characteristics. Polycentric and multilayered institutions are the key steps in the directions for AG. These arrangements, along with leadership, trust, and social capital, can enhance the likelihood for participation and collaboration. Self-organization can be done formally or informally by whichever social arena formed and practiced in different forms of networks. These networks in turn help enhance learning and innovation, which can create enabling conditions for building resilience. The dashed lines represent indirect relationships. The existence of polycentric and multilayered institutions helps to encourage self-organization and the formation of networks and vice versa, while participation and collaboration can further accelerate learning and innovation.

The discussion below explores each of these four characteristics. It does so with a number of key issues in mind.

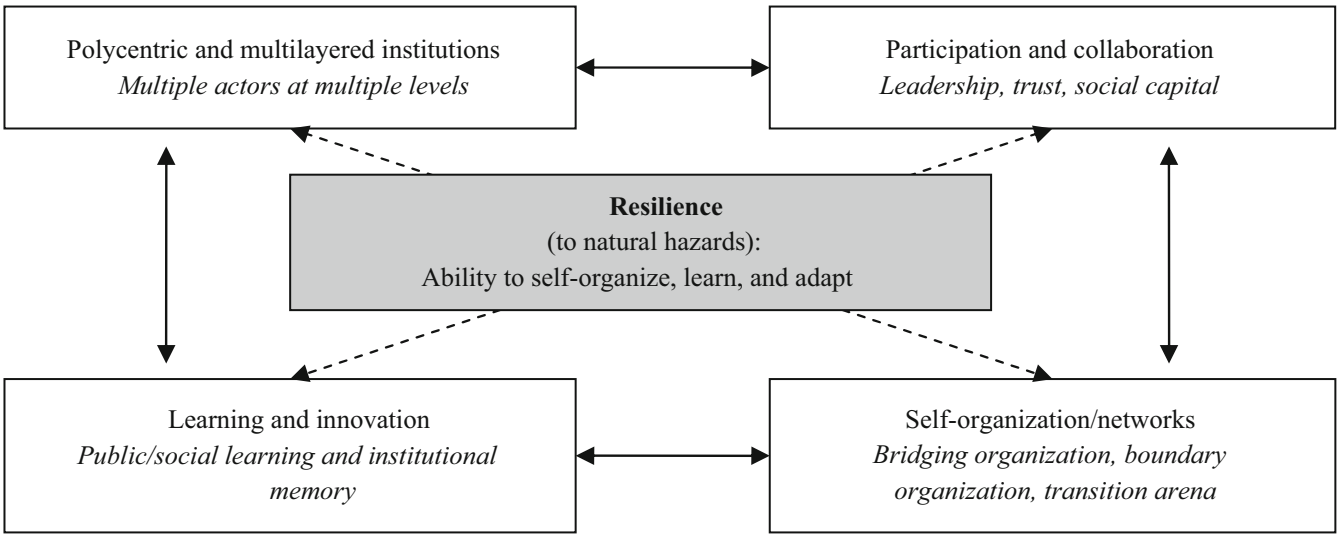

Figure 1. Interlinkages between key characteristics of adaptive governance (AG) in relation to building resilience

Initially, for each characteristic, the discussion briefly explains how the concept is understood in the AG literature. It then identifies some of the key lessons learned from the AG literature about its strengths, weaknesses, and trade-offs within the AG context. The discussion then examines the links between the characteristic and resilience from the perspective of the AG literature and explores whether and to what extent the characteristic has been recognized in DRR contexts and studies. Finally, the discussion identifies the insights for building resilience that can be taken from the AG literature, to enhance DRR planning and implementation.

3.1 Polycentric and Multilayered Institutions

Polycentric governance systems (McGinnis 1999) are characterized by the existence of various kinds of governing authorities at different governance scales. For example, a variety of non-state actors may assume administrative, regulatory, managerial, and mediating functions previously undertaken by a central government. This polycentric vision conceives of many centers of decision making and action that are formally independent of each other, but that can function either independently or constitute an interdependent system of relations (Ostrom, Tiebout, and Warren 1961).

Our review shows that polycentric and multilayered institutions have a very high potential to influence the capacity to manage resilience. The existence of different organizations at different scales allows for scale matching of organizational and ecological scales (Folke et al. 2005). These institutional arrangements improve the fit between knowledge, action, and social-ecological processes to help societal adaptation at the appropriate level (Lebel et al. 2006) and create possibilities for moderating vertical interplay among institutions (Young 2002). Lebel et al. (2006) observed that multiple and interdependent structures as suggested by polycentric institutions allow for opportunities for local institutions which can better match the social-ecological contexts and dynamics. This arrangement can enhance trust and cooperation, and may achieve more effective, equitable, and sustainable outcomes (Toonen 2011). Opportunities for learning and innovation through utilization of local and multiple sources of knowledge can also lead to better adaptation strategies (Ostrom 2010). Through the pooling of knowledge, a comprehensive assessment of problems can be performed, uncertainties can be reduced, the results are more likely to be accepted, legitimacy is increased, and innovations can be expected (Berkes and Folke 2002). Polycentricism allows for institutional interactions to improve the diversity of responses and stimulate collaboration (Folke et al. 2005). Over the medium to long term, redundancy can be structurally increased and failure is likely to be reduced (Ostrom 2010).

There are some trade-offs in the context of polycentric and multilayered institutions. In the short term, multilevel and multiple decision-making centers can heighten transaction costs and decrease efficiency (Pahl-Wostl 2009) and opportunities for collective action can be missed (Folke et al. 2005). There can be inefficient overlapping of coordination and administrative responsibilities (Lebel et al. 2006), which can be potentially ineffective if lower government levels do not have power and resources (Bulkeley and Betsill 2005). Another challenge is joining up agencies and governments to willingly share power. Many studies in collaborative natural resource management and watershed management have provided evidence that cooperation at these higher levels poses one of the greatest challenges to the effectiveness of multilevel nested collaboration models (Freeman and Farber 2005; Margerum 2008). One way of overcoming this is for national governments to provide sufficient incentives (legal and economic) to ensure lower-level bodies have sufficient motivation to genuinely engage in joint governance processes

(Karkkainen 2001; Holley, Gunningham, and Shearing 2011).

Implications for resilience to natural hazards

The literature on DRR and climate change adaptation shows that multilevel climate risk governance has been proposed as one strategy to manage the impacts of climate change (Bulkeley and Betsill 2005; Corfee-Morlot et al. 2011). Cross-sectoral regional or urban development strategies implemented between local and national governments are likely to improve the effectiveness of policies that promote mitigation and adaptation to climate change (Corfee-Morlot et al. 2011). Although adaptation policy needs to be guided by national policy, implementation needs to take into account local priorities and contextual differences in the geophysical and socioeconomic environment (UNFCCC 2008; IFRC et al. 2009).

Governing for climate change requires the provision of an open, deliberative space for local stakeholders through which multilevel climate risk governance can provide such space. Hazard management case studies in Canada and India show that cross-scale institutional linkages are particularly effective means by which to build resilience in mountain social-ecological systems in the face of all hazards (Gardner and Dekens 2007). Adger et al. (2005) suggested that a multilevel governance system for disaster management enables enhancement of capacity to deal with uncertainties through mobilization of different sources of resilience. Taking the example of the 2004 Indian Ocean tsunami, they argued that the existence of formal and informal institutions as well as large-scale international response helped the affected countries to cope with and recover from the impacts quicker and better, and even permitted the use of the tsunami as a window of opportunity for building long-term community resilience.

There are, however, some obstacles for implementing these institutional arrangements for managing resilience. Devolution of power through decentralization is ineffective without transfer of specific authority and power. For example, a lack of technical capacity or access can hinder adaptation planning at the local level despite the existence of a nationally guided plan on climate change (Bulkeley and Betsill 2005; Corfee-Morlot et al. 2011). Thomalla and Larsen (2010) observed that local government agencies and NGOs can be locked in a power struggle if the roles and responsibilities of different actors are unclear or if the legitimacy of some stakeholders is questioned. During emergencies resulting from natural disasters, local governments and other local entities have crucial and difficult tasks to undertake. They must coordinate, facilitate, and encourage all local stakeholders to engage in response and recovery efforts. This organizational and inspirational role poses serious challenges at the best of times. But they constitute almost impossible demands because they arise at a moment when these institutions have neither the resources nor capacity to do so, and may have lost both critical infrastructure and personnel as a result of the disaster's impact (King 2008; Brody, Kang, and Bernhardt 2010; Jabeen, Johnson, and Allen 2010).

The discussion above suggests that polycentric and multilayered institutional arrangements recognized in the AG literature have been equally canvassed within the DRR literature, not least because place matters in terms of how risks are perceived and socially constructed. The main obstacle tends to be how local actors are to be equipped with the necessary skills and resources, and in most cases such capacity building is generally expected to emerge through cooperation between higher-level institutions/organizations and lower-level actors. Experience from the AG literature suggests that this will be a difficult challenge, and it is one that has perhaps been downplayed in the DRR literature to date. Anticipating and responding to potential ineffectiveness and inefficiencies within the vertical and horizontal relationships between organizations is an issue that requires further attention from both policy makers and scholars, including exploring options such as the use of legal and economic incentives identified in AG, as well as other means to achieve more effective polycentric arrangements.

3.2 Participation and Collaboration

Participation is a multifaceted concept and debates vary depending on which feature of the participatory process is discussed (Fung 2006). For example, participation (that is, deliberation) as communication is a common area of concern in the literature. Deliberation can take place in many settings, both formal and informal, including through networks (Dryzek 1999). Generally, collaboration can be defined as a process where a group of diverse stakeholders, including government and nongovernment actors, and individuals and communities pool their knowledge and/or tangible resources to solve shared environmental or natural resource dilemmas (Parker and Braithwaite 2003). It can take place in different ways and involve different actors. Collaborative relationships may be one-off events, but many are ongoing processes, where stakeholders plan, implement, monitor, and adapt their actions over time. Some involve only government agencies, others involve only citizens, some involve both (Margerum 2008; Holley 2010b). Participation and collaboration favorably influence the capacity to manage resilience. The pooling of knowledge from multiple participants can allow for effective processes and better outcomes (Pahl-Wostl 2009).

The AG literature recognizes a range of factors that affect participation and collaboration. This includes leadership experience and quality, transactions costs, the extent to which solutions derived from collaboration bind all collaborating parties, and how group identities and allegiances are formed and organized (Karkkainen 2001). Equally important are the collective experiences of collaboration, and the external forces or influences that affect collaborative efforts (Heikkila and Gerlak 2005). Ostrom's research on the effective and

sustainable comanagement of common pool resources (CPR) has identified a range of conditions (such as trust, severe environmental problems, and autonomy from external authorities) associated with an increased likelihood of successful self-organized collaboration in the CPR context (Ostrom 1990, 2000).

Effectiveness can be reduced because a participatory approach is resource-consuming (Pahl-Wostl 2009). When membership is not representative or involvement is not meaningful, the legitimacy of the processes and outcomes may also be challenged (Pahl-Wostl 2009). Bias and incomplete knowledge can undermine participation (Jasanoff and Wynne 1998). It can also lead to additional conflict and can result in lowest common denominator solutions and imprecision (Orts and Coglianese 2007). Free-riding, fear of future defection, lack of trust, and high transaction costs can all hinder collaboration (Heikkila and Gerlak 2005; Raymond 2006; Holley 2010b).

In many instances, the initial challenge is getting relevant parties to the table. Many studies into collaborative forms of AG have found that the existence of external and institutional triggers are vital to opening the way to successful collaboration by creating the necessary incentives to engage stakeholders (Roux, Murray, and van Wyk 2007; Tompkins, Few, and Brown 2008; Hunt and Watkiss 2011). It is important to recognize that collaboration not only requires bringing actors together, but also maintaining participatory and collaborative responses over the longer term. Studies into collaborative forms of environmental management have emphasized the need for a strong ongoing governmental role, including funding and/or in-kind assistance to offset the inevitably high transaction costs that confront volunteers engaged in day-to-day decision making and action (Freeman 1997–1998; Freeman and Farber 2005; Holley 2009). Such support can be particularly vital when dealing with marginalized populations. In such situations, government will need to provide the necessary support to ensure that marginalized actors are given a voice in decision making (Freeman 1997–1998; Lane and Corbett 2005). The primary lesson to be taken from AG is that to successfully engage all stakeholders as volunteer partners requires funding to be commensurate with their time scarcity and financial needs. Without this, some groups, those with the least time and resources to spare, will not participate (Lane and Corbett 2005) or lose interest in the long term (Holley 2009; Thomalla and Larsen 2010). The long-term sustainability of disaster preparedness activities based on volunteerism is a particular challenge for DRR (Thomalla and Larsen 2010).

Implications for resilience to natural hazards

Many disaster studies have pointed out the importance of participation and collaboration by different stakeholders at different stages of the planning and management of disasters (Berke, Kartez, and Wenger 1993; Warner, Waalewijn, and Hilhost 2002; Sharp 2007; Warner 2008; Tran et al. 2009; MacRae and Hodgkin 2011). Pearce (2003) argued that sustainable hazard planning and management can only be achieved through community participation within disaster management. The example of Portola Valley in the San Francisco Bay area is a case in point. The town is frequently hit by landslides because it is located on the San Andreas Fault. Pearce (2003) outlined how disaster management planning by the valley authority benefited from the involvement, leadership, and participation of several community members who formed a geologic hazard committee. A study in the Cayman Islands showed that stakeholder participation, access to knowledge, accountability, and transparency in DRR policy created a policy environment that is conducive to the kind of structural reform needed to build long-term adaptive capacity to climate-driven impacts (Tompkins, Lemos, and Boyd 2008). A coastal zoning study in eastern Quebec, Canada reported that efficiency in implementing various zoning measures was dramatically improved through close collaboration of scientists, management, government, and the public (Drejza, Bernatchez, and Dugas 2011).

Social capital, defined as the norms and social relations within societies' social structures that enable coordination and actions to achieve desired goals (Sharma and Patt 2012), has also been identified as an important element to help a community be more resilient to disasters. According to Aldrich (2011), social capital was the strongest and most robust predictor for population recovery after the 1995 Kobe earthquake in Japan. It was found that after the earthquake, social capital was manifest in terms of the creation of neighborhood-based civil society organizations within different wards in the city of Kobe and this helped to organize and coordinate faster recovery activities. Comparing two similar neighborhoods affected by the Kobe earthquake, Mano and Mikura, Aldrich found that stronger community networks in Mano helped to accelerate recovery after the disaster. The citizen fire brigade in Mano successfully fought post-quake fires compared to similar network in Mikura. People in Mano ward have also undertaken various community activities such as the rehabilitation of the community center (Machizukuri office), the establishment of a community-managed company to help the reconstruction processes (Manokko), the lobbying for housing for the elderly, as well as campaigning for the construction of public houses for people affected by the disaster. Mikura, which has been shown to have weaker community ties, has only conducted one activity—the creation of an organization called Machi Community to help accelerate the reconstruction processes.

Despite Coglianese's observation (Orts and Coglianese 2007) that collaboration and participation can sometimes augment conflict, it is generally viewed favorably in most post-disaster activities, especially in places with inequalities, conflicts, and ethnic divisions. Public participation after the Bam earthquake in Iran helped to reduce possible economic, social, political, and cultural conflicts in already highly vulnerable communities (Omidvar, Zafari, and Khakpour 2011). The inclusion of existing local networks for aid distribution

helped to improve ethnic neutrality and social harmony after the 2004 Indian Ocean tsunami in Sri Lanka (Amarasiri de Silva 2009).

These case studies show that participation and collaboration are recognized as important in both AG and DRR to improve effectiveness and efficiency, and to reduce uncertainties in managing complex environmental problems. Important issues that have not been addressed sufficiently in DRR include the nature and degree of participation, the transaction costs, and the extent to which existing and potential conflict can be avoided or reduced through participation.

3.3 Self-Organization and Networks

A network is a self-organized and typically informal governance system in which diverse actors are knitted together across organizational levels to focus on common problems (Folke et al. 2005, 450). Networks are actualized through boundary organizations, bridging organizations, or epistemic communities.

Boundary organizations are described as the arenas for multiple entities to reach a common understanding of issues (Corfee-Morlot et al. 2011). A boundary organization is a place for scientists and decision makers to meet to create a boundary arena that is acceptable and accountable to all parties involved (Guston 2001). A bridging organization has a broader scope than a boundary organization (Brown 1991). Examples of a bridging organization include an assessment team composed of different actors in a social-ecological system, NGOs that create a social arena, and the scientific community that can facilitate and control adaptive management processes (Garmestani, Craig, and Cabezas 2008). An epistemic or policy community is a governance system consisting of different agents operating at different levels, formed through a similar interest in influencing and implementing policies (Folke et al. 2005). It can exist in the form of a formal collaboration or a comanagement structure in which management authority is shared by multiple stakeholders. Such a comanagement arrangement is often used by governments to increase legitimacy and manage conflicts without the devolution of power (Carlsson and Berkes 2005). Another known form of self-organization is the transition arena, in which problems and possible solutions are deliberately confronted and subsequently integrated to come up with an innovative and visionary agenda (Rotmans and Loorbach 2009).

Several challenges are identified in the literature to the flexible comanagement approach. Agencies themselves might resist change and refuse to have different forms of coordination beyond their mandates (Freeman and Farber 2005). Accountability can be difficult to determine and measure in a flexible arrangement. If a new institution is formed, new layers of accountability can emerge (Freeman and Farber 2005). Duit et al. (2010) warned that heavy reliance on self-organized networks in managing social-ecological systems can lead to government failure since its empirical applications are still rare.

Implications for resilience to natural hazards

There is an increasing emphasis in the literature on the need for flexible organizations, policies, and institutions in managing and reducing disasters (Bull-Kamanga et al. 2003; Klein, Nicholls, and Thomalla 2003; King 2007; Warner 2008). An abundance of case studies of community self-organization at different stages of disaster management exist (see, for example, Paton and Johnston 2001; Menoni 2001; Nakagawa and Shaw 2004; Srinivas and Nakagawa 2008; Surjan and Shaw 2009; Aldrich 2011). In Australia, King (2007) observed a "plethora of organizations" by which a community organizes itself after a disaster, reassigning priorities and using existing organizations and networks for new purposes. In Japan, jishu-bosai-soshiki, translated as the "autonomous organization for disaster reduction," takes effect during emergency situations (Bajek, Matsuda, and Okada 2008). This neighborhood association is actively involved in community preparedness and rescue activities throughout Japan.

Humanitarian organizations, NGOs, and civil society organizations have extremely important roles in DRR. The flexibility in their operations, generally in terms of ability to speed-up deployment of resources without having to pass long bureaucracy than what formal governments normally have to face, enables them to support communities at every stage of the disaster management cycle (prevention, mitigation, emergency, and recovery) (Telford and Cosgrave 2007) and climate change adaptation strategies (Bulkeley and Kern 2006).

The importance of a multi-stakeholder forum in helping to create space for collaboration and learning has been acknowledged by the UNISDR. The Global Platform for DRR was established in 2007 along with six regional and 60 national platforms worldwide (UNISDR 2011). A report by the United Nations Development Program (UNDP) revealed that the Indonesian national platform for DRR was formed smoothly because of the existence of a previous analogous entity and because it was supported by the recently passed law 24/2007 on Disaster Management (UNDP Indonesia 2008). Without these preconditions, the formation of such a platform might have been difficult to initiate. Based on similar cases of multi-stakeholder forums in Ica and Ayacucho in Peru, Warner and Oré (2006) warned that without larger institutional stability such platforms might not be sustainable in the long term. In line with Berkes' (2009) observation, the multi-stakeholder participation in Ayacucho was created as a strategy for the national government to increase its legitimacy and manage conflicts without the devolution of power.

There is an increasing recognition of the role of alternative governance systems in addressing global environmental changes and risks. Local governments around the world are actively involved in innovative networks to encourage the sharing of experience and lessons learned. These include Cities for Climate Protection by the International Council for Local Environmental Initiatives (ICLEI),[i] Climate Resilience Cities by the World Bank,[ii] and the Resilient Cities campaign

by the UNISDR,[iii] to name but a few. All of these are networks of cities in developing and developed countries that have come to the realization that local actors are the first respondents against any impacts of natural disasters or climate change risks. Because cities have a great potential in implementing both mitigation and adaptation to climate change simultaneously, direct links between them enables the transfer of knowledge and facilitates social learning.

That a transition arena can help to create innovation in DRR is demonstrated by the San Diego Fire Recovery Network. This is a community self-organized network that was formed due to a perceived inability of the government to respond to disasters in a timely fashion (Goldstein and Butler 2009). It is considered an innovation since it altered residential knowledge practices and identity and reshaped governance relationships. Nonetheless, Rotmans and Loorbach (2009) remind us that a transition arena still needs to be supported with a mechanism to assess and evaluate performance, otherwise capacity to innovate further can be undermined.

The above discussion shows that self-organization and networks are important and have been considered extensively in DRR. Many benefits that demonstrate how self-organization and networks help to build community resilience locally or internationally have been documented. Although beyond the scope of this article, it is possible that these documented experiences could contribute useful insights to the AG literature on self-organization and networks. Some issues identified in the AG literature, such as the resistance of organizations to change, and the challenges of identifying who is accountable for what within loose and informal networks, do not appear to have been fully recognized or addressed within the DRR literature.

3.4 Learning and Innovation

Learning emphasizes active social participation and dynamic integration between people and the environment to construct meaning and identity (Lave and Wenger 1991). One key term developed for continuous learning is public or social learning. Public learning implies an ability to learn the consequences of one's action to the broader public (Scholz and Stiftel 2005), sometimes termed social, institutional, or organizational learning. It is a form of public learning within formal, informal, or loosely defined organizations (Folke et al. 2005). Social learning is facilitated through the accumulation of social-ecological learning and understanding—this is also referred to as "social memory." It is essentially accumulated experiences, values, debates, and decision-making processes that have been used as strategies to continually deal with change. When this memory is stored within institutions, it is called institutional memory or a knowledge system, or reservoir, of long-term social-ecological adaptation to change (Berkes and Folke 2002). Resilience is greatly enhanced through learning and innovation (Folke et al. 2005). Learning allows for diverse access to a new kind of knowledge and diverse assessments (Pahl-Wostl 2009). It also creates arenas for novelty and innovation (Folke et al. 2005). Continuous learning is necessary to keep up with change and uncertainty in complex adaptive systems (Carpenter and Gunderson 2001; Englehardt and Simmons 2002).

Another prominent form of learning is an adaptive management approach to dealing with natural resource and environmental problems. Within AG, documented instances of successful adaptive management of natural resources are rare (Doremus et al. 2011). Studies into groundwater and surface water (Holley and Sinclair 2011), the Florida everglades (Gunderson and Light 2006; Walters, Gunderson, and Holling 1992), species and habitat conservation (Gunderson 1999; Karkkainen 2003; Doremus et al. 2011), and natural resource management (Wondolleck and Yaffee 2000) have identified a number of practical challenges that have stood in the way of establishing successful learning. Acknowledging these failures and the conditions that have produced them can ensure that DRR can confront these challenges head-on and avoid pitfalls.

One significant practical problem for achieving learning in the context of AG is the technical, logistical, and financial challenges that often stymie the collection of baseline environmental data (for example, the precise quality or quantity of groundwater) on which to judge whether a management action by a given body is effective in producing the desired result (Steinzor 2000). Thomalla and Larsen (2010) observed within community-based DRR, that a similar practical challenge is to identify, agree on, and measure a desired outcome of resilience building.

A lack of government investment, coordination between agencies, and a culture that lacks the flexibility needed for learning (Gunderson 1999), or prefers on the ground outcomes to investment in long-term monitoring has also been shown to be a particular problem (Holley 2010a). Others have explored the conditions under which local collaborations will be capable of being effective ongoing monitors of their own actions and the impacts of these actions on environmental conditions (Fung and Wright 2003; Holley 2009). The tasks of monitoring can also raise a range of complex issues for local collaborations, including clarity about the causal relationships between management actions and changes to environmental conditions and the time frame of changes to environmental conditions in response to management interventions (Dovers 2003b).

A range of challenges prevent effective monitoring, including insufficient resources and training provided to citizen volunteers to conduct comprehensive monitoring; insufficient internal expertise to conduct learning and adaption (for example, hydrological staff to not just carry out robust monitoring, but equally to compile, interpret, and analyze collected data); and the sheer complexity and scope of environmental problems that spread over large geographical areas (Holley and Sinclair 2011). Frequently, short-term project planning and implementation does not allow for the monitoring and evaluation of long-term processes. These experiences from practice suggest comparable investment

and support is needed to substantially increase the extent and effectiveness of basic monitoring of the environment and management actions in order to better support learning approaches (Doremus et al. 2011).

Overcoming a lack of coordination, relevance, and access to government monitoring data that has plagued AG approaches similarly demands clarity on why data are collected, who is to collect it, and who has access to it (Karkkainen 2006). In particular, many have recommended legislating detailed statutory mandates for collecting and sharing data across bureaucratic fiefdoms (Camacho 2007; Benson and Garmestani 2011; Doremus Forthcoming). Others have proposed creating a separate monitoring agency or establishing an expert monitoring panel, NGO, or other intermediary organization to pool, network, and diffuse monitoring and learning information which enjoys the trust, respect, and attention of both knowledge producers and knowledge consumers (Gunderson 1999; Wondolleck and Yaffee 2000; Doremus Forthcoming). Alternatively, proposals suggest looking beyond agencies to better incentives, to fund and support nongovernment actors to collect data.

The experience to date suggests that policy makers should, at the very least, carefully assess the expectations they place on community or collaborative bodies to perform learning tasks, particularly the scope and detail of monitoring and evaluation that can and should be deployed (Dart and Davies 2003). Any community-driven data gathering processes to establish baselines and to demonstrate intermediate outcomes in adaptive processes will require that sufficient support is provided (Karkkainen 2003). Alternatively, government may look to harness (through monetary or regulatory incentives) more well-resourced actors like industries that have been shown to be better equipped at fulfilling monitoring tasks (Dovers 2003b; Karkkainen 2003; Holley 2010a).

Ultimately, a primary lesson from AG is that processes for establishing learning arrangements do not emerge spontaneously. Simply layering learning processes and goals on top of governance programs demonstrably does not provoke meaningful learning. They have to be explicitly and effectively designed, supported, and encouraged (Head 2009; Ruhl 2011).

Implications for resilience to natural hazards

Learning is seen as a positive characteristic in the DRR literature. A study that examined social learning within communities in flood-prone areas in Puerto Rico found that social learning can be promoted through building on existing knowledge. By combining local community knowledge about flood hazard coping strategies with scientific information on how flood characteristics are affected by human activity and climate change more effective management practices emerged (López-Marrero and Tschakert 2011). A case study of the Cayman Islands showed that persuasion, public education, and prior disaster experience lead people to change their attitude toward climate risk management, which resulted in the formation of informal action groups (through the participation of volunteers) and increased collective action (Tompkins 2005). In many places, local knowledge and practices have helped communities to cope with and respond to natural hazards and environmental change for generations. These local/indigenous knowledge and practices need to be integrated with scientific knowledge when designing local disaster preparedness and adaptation strategies (Mercer et al. 2009).

Social memory is a critical element in helping to reconstruct past adjustments to climate change. In the case of Hurricane Katrina this basic management tool was ignored. Historical records compiled after Hurricane Betsy in 1965 were neglected and this led to devastating impacts during Hurricane Katrina in 2005 (Colten and Sumpter 2009). In a recent study on building resilience to disasters in Indonesia, Djalante et al. (In Press) found that in areas affected by major and frequent disasters, local government agencies and NGOs tend to have more awareness on the importance of DRR. Sharma and Patt (2012) examined the effect of personal experience of hurricanes on peoples' responses to early warnings and demonstrated the importance of three factors: the severity of the past impact, past experiences with false alarms, and past experiences with evacuation services.

Even though the experience in AG shows that learning creates arenas for novelty and innovation, the latter might be difficult to achieve in a disaster setting. A study in Sri Lanka after the 2004 tsunami revealed that innovations in disaster recovery require distinct approaches, resources, and competence. The combination of ineffective government, weak markets, civil war, and the enormity of the tsunami recovery needs all undermined the ability to innovate (Koria 2009). Voss and Wagner (2010) found that institutional learning from small-scale disasters rarely takes place because the stakeholders' focus remains on only one governance level. They argued that learning lessons from small disasters (for example, a flash flood in a small town) is extremely important to help reduce possible damage and even catastrophic disasters in the future. This has strong implications for DRR. For example, the Intergovernmental Panel on Climate Change (IPCC 2007) expects an increase in the number of small-scale, incremental disasters due to climate change. If institutions cannot learn from these incremental disasters, their resilience might be eroded and they might not have the capacity to cope with a succession of small-scale events or sudden and/or large-scale events. Eroded resilience and increased vulnerability can easily turn small-scale hazards into catastrophic disasters (Wisner et al. 2004). It is also equally important to facilitate learning at all stages of the disaster cycle (Berke, Kartez, and Wenger 1993; Murphy 2007; Pelling 2007; Chang and Chang 2010; Paton et al. 2010). There are abundant examples of learning failures from the AG literature that can provide lessons for DRR, including how learning can be more systematically supported, adopted, and implemented. There are also issues of learning that may be specific to a particular disaster context. This may warrant further exploration to test and refine the lessons from AG in the DRR context.

The previous discussion is summarized in Table 1. It shows the potential of the four AG characteristics in increasing disaster resilience, the direction of the contributions between the two bodies of literature, and some examples of the potential contributions from AG to DRR.

4 Conclusion

We have outlined how adaptive governance (AG) can increase resilience to natural hazards. We have reviewed the basic concepts of AG and disaster risk reduction (DRR), and examined the four important characteristics for managing resilience (polycentric and multilayered institutions, participation and collaboration, self-organization and networks, and learning and innovation). We have also identified the important interlinkages between these characteristics. While some aspects of AG we have reviewed have long been considered within DRR, there is scope for more lessons to be learned.

The importance of polycentric governance for DRR has been recognized and implemented worldwide. However, the experience from AG shows that the higher levels of government need to provide considerably more technical and financial support to agencies and organizations operating at the lower governance levels.

Effective participation and meaningful collaboration between all stakeholders, governments, NGOs, and communities has also been pursued as an important element of DRR. An increased recognition of the roles and responsibilities of local stakeholders in managing disasters and climate change risks is crucial. A key lesson from AG is that preexisting inequalities, a lack of trust, and ineffective government can significantly hamper participation and collaboration. The increasing focus on climate change adaptation creates a window of opportunity to rethink development and DRR (Ireland 2010) and to create innovative partnerships between public and private-sector organizations.

The role of self-organization and networking is acknowledged in DRR to some degree but more lessons can be inferred from AG. For communities affected by disasters, reorganization is often taken to be a coping mechanism once a disaster has struck, rather than an element of longer-term building of resilience. The process of forming a network is important, since it can create cohesion and help to increase

Table 1. Relationships and directions of contributions in literature between adaptive governance (AG) and disaster risk reduction (DRR)

AG Characteristics	Implications for Resilience	Direction of Contribution of Literature	Potential Contributions from AG for More Effective DRR	Practical Example Identified in DRR Literature and Potential for Learning Based on AG Literature
Polycentric and Multilayered Institutions	Very high	DRR needs to learn more from AG.	Not many discussions in DRR literature were found on how the potential for ineffectiveness and inefficiencies can be overcome.	UNISDR system from global to local level, involving multitude of actors from global to local level. As suggested in AG literature, ineffectiveness and inefficiencies in implementing polycentric structures can be overcome through higher level governments providing incentives (legal and economic) to increase engagement of lower level actors.
Participation and Collaboration	High	There have been documented cases in AG and DRR literatures.	Three important issues that have not been addressed extensively within the DRR literature on participation are: (1) quality of participation; (2) issues of transaction costs; and (3) the extent to which conflict can be reduced through participation in a disaster-stricken place.	Public participation after the Bam earthquake has been recognized to reduce conflicts amongst the economically and socially segregated communities. As the AG literature suggests, it is therefore important that governments provide necessary support to make sure that the voices of marginalized groups within the community can be heard and that these groups can be involved in decision-making processes to help reduce further conflicts.
Self-Organization and Networks	High	There are many cases of the application of flexible networks in DRR. This can help enrich AG discussion.	DRR reviews showed that self-organization matters at the local level, and that network characteristics are different at different stages of disaster management.	Resilience cities program by the International Council for Local Environment Initiatives (ICLEI) has been extensively implemented in both developed and developing countries. Cities learn from each other on experiences and innovations in dealing with disasters and climate change risks. As revealed by the AG literature, willingness of higher level government agencies to collaborate or coordinate with the cities as well as accountability of these networks appear to be important areas to examine further.
Learning and Innovation	High	Experiences from AG are still underutilized for DRR.	There are also disaster-specific learning issues to be explored further. Furthermore, DRR needs to incorporate from AG how learning can be systematically adopted and implemented.	The multi-stakeholder platform for DRR in Indonesia has been able to help increase coordination as well as sharing of experiences of various organizations working on DRR. As suggested in AG literature, more systematic learning needs to be explicitly and effectively designed, supported, and encouraged to ensure that the experiences can be captured and learning can take place effectively and long term.

community resilience. Bridging organizations in the form of multi-stakeholder platforms for DRR are an example of innovative networks that have recently been established in many parts of the world. The success of Al Gore's Climate Project and Bill Clinton's Climate Leadership Groups demonstrates that we need more forms of flexible organizations that are composed of private actors with a strong interest in current environmental issues, and are implemented through local organizations. DRR at the local level can further benefit from an epistemic community consisting of local community and research institutions working together to identify local hazards and risks.

Learning and innovation are important elements of AG that have a high potential to contribute most strongly to DRR. While they are formally enshrined in one of five Priorities for Action within the global framework for DRR—the Hyogo Framework for Action (UNISDR 2007)—they have not been pursued consistently by the DRR community in practice. Little progress has been made in documenting systematically how and what organizations and nations have learned from past disasters, what innovations have resulted from them, and how learning can be better monitored and evaluated. Examples of innovations in DRR do exist but the documentation and dissemination of such successes remains poor. We advocate that more attention be paid to the lessons emerging from the AG literature, and that more research be conducted on how communities learn and innovate from different types of disasters and within all stages of DRR.

Ultimately, we have sought to open a space for DRR practitioners and scholars to pause for thought, to reconsider, and to reformulate their understanding of and orientation toward governing to build resilience. Through an interdisciplinary approach, we have highlighted novel perspectives and identified links between the DRR and AG literature. Our hope is that this approach will motivate others to look to AG and elsewhere to build a better and more robust theory for resilience governance in DRR. Building the resilience of communities and societies to natural hazards and climate change impacts is not just an outcome, but also a (long and challenging) process (Djalante and Thomalla 2011). It is imperative to consider the lessons of AG and other related environmental governance fields in order to help broaden, strengthen, and fast-track our understanding and implementation of resilience.

Notes

i http://www.iclei.org/ index.php?id=about.
ii http://www.worldbank.org/eap/climatecities.
iii http://www.unisdr.org/english/campaigns/campaign2010-2015/.

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